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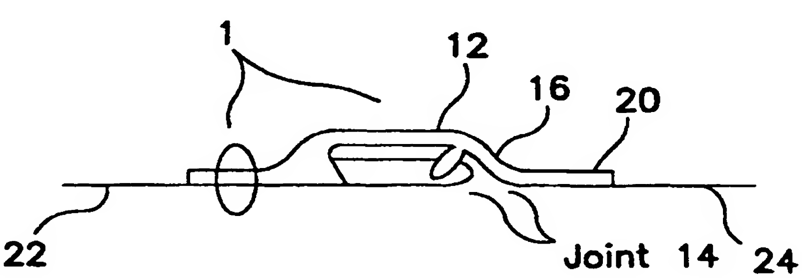

(57) Abstract: A fabric that is for protection against ingress of water, chemicals, or blood borne pathogens, including a seam joint (14), in which the seam is sealed by a sealing backer (20), and a silicone layer (16) between the sealing backer (20) and the joint (14). The fabric may be used in a variety of protective barrier garment applications including rainwear, fire fighting garments, and medical operating gowns. The process for preparing the seam is to apply liquid uncross-linked silicone to the sealing backer (20), followed by consolidating the sealant covered backer over the seam and curing the polymer in an extended heated nip.

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SEAM SEAL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to protective garments that protect the wearer from undesirable fluids. More particularly, it relates to the sealing of seams in such garments. The improved seam seal of the present invention provides a construction that uses cross-linked silicone elastomers as a sealant and an adhesive layer to seal a seam tape to the garment fabric, allowing the special properties of these elastomers to be exploited to improve the performance and durability of the seams. Additionally, the invention provides a method for sealing protective garment seams.

2. Description of Related Art

Existing Seam Seals

Many protective garments employ seam seals to maintain the integrity of the protective barrier across the seam. One area is rainwear where the garment protects the wearer from water. Other areas include medical operating room gowns that protect the wearer from blood borne pathogens and fire service turnout coats that protect the wearer from multiple threats, including water, blood borne pathogens, and chemicals commonly encountered in fires and other emergency situations.

The seam seals often must withstand hostile environmental conditions. For example, firefighter's turnout gear, including the seams, must withstand high temperatures without melting. In seams in surgical protective garments, it is desirable that the seal be autoclave sterilized numerous times while retaining its barrier properties.

Protective garments are made of a number of special protective barrier fabrics that include a protective barrier layer and other coverings or carrier layers, such as backing or face fabrics. In these garments the protective barrier layer performs the purpose of protecting the wearer from a threat to well-being, such as rain, snow, chemicals, viruses or blood pathogens. Examples include microporous polytetrafluoroethylene membranes, microporous or monolithic polyurethane membranes, and polyetherpolyester

membranes. The protective barrier layers may be attached to or laminated to one or more layers of covering, usually a woven or knit fabric layer to form a protective barrier fabric.

Garments are assembled from these fabrics by sewing panels of protective barrier fabric into the garment shape. The joints between the panels and other disruptions of the barrier layer are sealed so that the seal provides a barrier function comparable to the protective barrier fabric. This generally is accomplished by applying a thermoplastic tape over the seam. The tape is softened by hot air and applied over the seam by a specialized machine. The tape most commonly includes at least two layers where one layer has a melting point higher than the other layer. This allows the hot air sealing machine to melt the lower melting sealing layer, leaving the higher melting layer intact as a carrier.

Typically, thermoplastic adhesives are used to seal fabric seams. Thermoplastic adhesives such as polyurethanes, polyesters, and polyamides are used. However, thermoplastic adhesives suffer from numerous disadvantages including temperature limitations, limited durability and susceptibility to some chemicals.

Also, the properties of the thermoplastic sealant generally limit the use of protective garments to environments where the adhesive is not degraded. For instance, the thermal instability of thermoplastic sealing adhesives limits the use of the barrier layer in fire service garments to inner layers where temperatures tend not to exceed the melting point of the adhesive. In addition, the thermoplastics are limited in their ability to penetrate porous cover fabric layers or microporous barriers. Sealing protective barrier fabrics often requires penetration of layers in the fabric or of a portion of the protective barrier layer. Design of the sealing side of protective barrier fabrics generally is limited to surfaces that can be penetrated by the relatively viscous thermoplastics.

<u>Silicone in General</u>

Cross-linked silicones have a number of desirable properties for use as a seam sealant component, including thermal stability, recoverable stretch with low elastic modulus, and resistance to a number of chemicals and water. Silicones are well known as sealants and are commonly used to seal against water and fluid ingress in building construction, automobiles, and a number of

other applications. Additionally, before cross-linking, these elastomers are generally liquids with low viscosity, or shear thinning pastes that exhibit low viscosity behavior under shear.

The silicones can be formulated from a one component or two component system. In a two-part system, the two components must be mixed before use. A one-part system requires no mixing before use. Such silicone systems are readily available from several companies worldwide, including General Electric Silicones, Waterbury, N.Y., Dow Corning, Midland, MI, and Wacker Silicones, Adrian, MI.

Despite the desirable properties of cross-linkable silicones, other properties of these silicones make it difficult to use them for seam sealing a wide range of protective garments. The systems are liquids at room temperature and cannot be used in the normal thermoplastic tape form for seam sealing. These liquids flow easily and have little strength in their uncured state. The flow of the liquid makes it difficult to ensure a substantially continuous layer of sealant over the seam. High points in the seam, such as stitching, often push through the sealant, forming leak paths. Yet another issue is that, except for specialized formulations, silicones do not adhere well to organic polymers. Moreover, cure times are long compared to the time for simple cooling of a thermoplastic adhesive. Cure times of at least several seconds to several hours are typical, compared to a process residence time of less than a second for thermoplastic sealing tapes. Also, such silicones generally do not provide a durable seam seal. Thus, despite the attractiveness of using silicone in seals, a number of important difficulties must be overcome to process these adhesives into garment seam seals.

<u>Sealing With Silicone</u>

Attempts have been made to overcome the difficulties and take advantage of the special properties of silicone in protective garment seams. However, all have limited success or have very limited application. U.S. Patent No. 4,733,413, issued to Dykstra describes a caulked glove seam using silicone beads applied to the side of the seam away from the seam allowance. These caulked seams are enclosed in the glove where the unsightly caulk line is not visible. This caulk bead method provides a bulky seal and is inappropriate for most garments where the face must have good appearance.

U.S. Patent No. 5,289,644, issued to Driscoll, suggests the use of silicone sealants in the soles of waterproof footwear. In this application, a specific footwear to a specific footwear construction, the seal is between the waterproof protective barrier fabric and a waterproof insole. The sole and the tooling inside the shoe provide a mold for the silicone and hold it in place while it cures. Tooling for garment manufacture in this fashion would be impractical.

Another attempt to provide a silicone seal in protective garments involves the use of small tubes of polymer sewn into the seams (DE 4025291 and DE 4223852). The tubes are perforated by the sewing needle and the silicone spreads through the seam area. This method is limited to a special class of seams that form a mold for the reactive liquid to cure and is impractical due to the contamination of sewing needles with the silicone. JP Appl 2-170868 and 2-170869 to Nakao, describes a complex apparatus for sealing seams in articles with a silicone membrane. This process is focused on circular articles, is limited to applications using both silicone sealing backers and silicone membranes, requires use of a carrier tape to handle the fragile silicone backer, and is not easily extended to general fabrication of protective garments. The process provides no molding during cure of a reactive liquid elastomer and is therefore limited to pressure sensitive adhesives with limited flow and sealing capability. U.S. Patent No. 4,303,712, issued to Woodruff, also describes a seam sealed with silicone adhesive in which the protective membrane and the backer are both silicone. This seal has sealing adhesive only along the outside edges and will have limited durability due to the limited joining area and the unattached backer in the sewing region.

Seals in structures outside the field of protective garments illustrate the challenges with using silicone and provide solutions applicable to their situations, but not garments. For instance, U.S. Patent No. 4,046,933, issued to Stefanik, describes a method of applying silicone sealant to an aircraft window where a silicone impregnated fabric tape is applied in the window frame, the window is added and the assembly is cured in an autoclave. The need for a mold is provided by the rigid window frame structure. The need for metered application of the reactive liquid is met by pre-impregnating the fabric tape with silicone and using the tape to meter the liquid. Unfortunately, garments do not have the integral tooling of the window and the autoclave

curing process is impractical. This method is not compatible with the fast cure time required for economical garment fabrication.

Thus, the design and use of protective garments is limited by the current thermoplastic sealing method and the properties of the thermoplastic sealing polymers. These polymers are limited in their use temperatures, by their ability to adhere to some barrier surfaces, such as polytetrafluoroethylene, by their ability to penetrate and seal textiles, and by their stiffness. Silicones have desirable thermal, flow, and softness properties that can address these shortcomings. However, it has not been possible to use these silicones in a seam seal construction or process that can be used in a wide variety of protective garments.

Accordingly, the present invention addresses deficiencies found in prior attempts to use silicone sealants in protective garment seams.

It is a purpose of the present invention to provide a seam seal in protective garments that protects the wearer from liquid or vapor threats such as water, chemicals, or biological fluids.

It is another purpose of the present invention to provide a seam seal construction whereby seams in protective garments are sealed with cross-linked silicones.

SUMMARY OF THE INVENTION

The seam construction of the present invention provides a seam seal that protects protective barrier fabrics from ingress through the seams of a variety of fluids, including water, blood, and chemicals by employing a sealing backer that seals the protective barrier fabrics over their seam joints with a silicone sealant layer. The sealing backer provides a sealing bridge; joined by the silicone sealant first to protective barrier fabric on one side of the seam; crossing over seam joints, and joining to an adjacent section of protective barrier fabric. The sealing backer provides the ability to bridge the seam joint between the fabric panels, resulting in the usefulness of this construction to a wide variety of protective garments. The sealing backer either is or contains a protective barrier layer, or becomes one after coating with silicone. The silicone layer provides a seal between the sealing backer and the seamed protective barrier fabric panels and adheres the sealing backer to the seam. Adhering substantially the entire width of the sealing backer to the seam

provides mechanical durability to the seam. The silicone also contains a reinforcing material such as fumed silica to provide increased mechanical durability and many contain platinum to increase curing speeds. The amount of fumed silica is preferably between 10-30% by weight based on weight of silicone.

The sealing backer can consist of the protective barrier layer alone or can be a composite of the barrier and a layer of any suitable covering fabric to provide strength and to protect the integrity of the protective barrier layer.

The protective barrier, both in the protective barrier fabric and the sealing backer can be any protective barrier. The protective barrier layer can be a membrane or film that protects against passage of undesirable agents, such as rain, virus, blood, pathogens, noxious gases, or chemicals. This barrier layer, whether in the protective fabric or in the sealing backer, is covered or laminated to supporting or protective layers of fabric to form a construction that goes into a garment. These fabrics are the usual fabrics, such as knits, wovens, non-wovens and the like, made of natural fibers, such as wool or cotton, or of synthetic fibers such as polyester or polyamide.

It is preferred that the protective barrier be a film or membrane that is porous. Porous membranes can be constructed to provide protection against penetration by several agents, such, for example, liquid water and viruses by adjusting pore size and pore path. The pores, of course, must extend from one side of the membrane to the other. Representative protective barrier membranes include microporous polytetrafluoroethylenes, polyurethanes, polyamides, polyesters, polyacrylates, polyolefins, copolyether esters, copolyether amides, and the like.

Fluoropolymers, including tetrafluoroethylene/(perfluoroalkyl) vinyl ether copolymer (PFA), tetrafluoroethylene/hexafluoropropylene copolymer (FEP), and polytetrafluoroethylene (PTFE), and the like, are preferred for their processing characteristics, heat resistance, and chemical inertness.

A particularly preferred membrane is expanded polytetrafluoroethylene which has a porous microstructure of nodes interconnected by fibrils to form an interconnected porous network.

Preferably, the protective barrier in the sealing backer and the protective barrier in the fabric are selected to allow impregnation of liquid uncross-linked silicone into the pores of the sealing backer membrane and the protective

barrier fabric panel. This provides mechanical bonding of the liquid silicone elastomer to the protective barrier and the sealing backer, allowing a more durable and stronger seam.

The process of the present invention provides a method for reliably sealing seams in protective barrier garments with a silicone sealing layer. The process includes applying liquid uncross-linked silicone to the sealing backer, followed by consolidating the sealant covered backer over the seam and curing the polymer in an extended heated nip. The extended nip includes a soft surface opposing a hard heated roll. The soft surface provides a mold-like restraint to maintain the uncross-linked silicone prepolymer in position until it is cured and cross-linked. Coating the backer before it is applied to the seam and providing a continuous mold provides the ability to seal garment seams of a variety of shapes and configurations with the process.

DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross section of a typical seam illustrating the construction of the invention.

Figures 1a through 1c illustrate cross sections of several variations of the construction.

Figure 2 is a scanning electron micrograph illustrating the penetration of the liquid silicone into the microporous structure of expanded polytetrafluoroethylene (ePTFE).

Figure 3 is a schematic of a process to make the seam construction of this invention.

Figure 4a shows the extended nip used in the process in which the nip is formed by a soft surface roller.

Figure 4b is a cross section of a seam as it passes through the extended nip, showing how the soft material of the extended nip forms a mold for the liquid silicone as it cures.

Figure 5 illustrates the extended nip formed by a belt apparatus.

DEFINITIONS

"Protective Barrier Fabric" means a fabric that blocks liquid penetration, wind, viral or chemical penetration.

"Protective Barrier Layer or Membrane or Polymer" means a layer, membrane or polymer that enables the Protective Barrier Fabric to pass any one of the following two tests:

a) Suter test, or

b) viral barrier test.

"Waterproof Seal" means a seal that passes the Suter test.

"Garment" means any body covering, including hats, bands, shoes, boots, socks, gloves, mittens, coats, skirts, pants, and the like.

"Protective Garment" means a garment that contains a protective barrier membrane or protective barrier fabric.

"Liquid silicone" means a silicone that is uncured, i.e., uncross-linked.

"Microporous" means a material that has pores that are too small to be seen by the naked eye and are connected with one another from one surface to the other.

"Membrane" means a sheet or film that is thin.

DETAILED DESCRIPTION OF THE INVENTION

Protective garments are formed by joining shaped pieces of protective barrier fabric into the three dimensional shape of the garment. The garments include seams where the fabric pieces are joined. Referring to Figure 1, the sealed seam 10 of the present invention includes a first panel of protective barrier fabric 22 joined to a second panel of protective barrier fabric 24 to form joint 14. A seal is applied over this joint to seal the openings created by the seam needles, so that the assembled garment has the barrier protection of the fabric. The seal construction includes a sealing backer 20 and a silicone sealing layer 16 applied across the seam. Sewing thread 12 joins adjacent protective barrier fabric panels to form the seam. The sealing backer 20 provides a sealing bridge from one side of the seam, across the joint 14, to the other side of the seam. Figure 1a illustrates a protective barrier fabric with a sealing backer 20 applied. The silicone layer 16 adheres the sealing backer 20 to the seam and provides a seal between the backer 20 and the protective barrier layer 30 (See Figs 1a, 1b and 1c) of the protective barrier fabrics 22, 24.

The panels can be joined by any of the typical sewn seams known to those skilled in the art of garment fabrication, such as simple seams, felled seams, topstitched seams, welded seams, etc.

In addition, the construction of this invention allows a number of protective barrier fabric configurations. For example, Figure 1a, 1b, and 1c illustrate a cross section of the seal region of the seam denoted by the oval in Figure 1. Figure 1a depicts a protective barrier layer 30 covered by a porous cover layer 36 to form the protective barrier fabric 22. The sealing backer 20 is adhered and sealed to the protective barrier layer 30 by silicone layer 16. Figure 1b is like Figure 1a except the sealing backer 20 includes a backer cover layer 32. Figure 1c illustrates a form of the seam construction where the protective barrier fabric 22 comprises outer porous cover layer 36, and inner porous layer 38 on both sides of protective barrier layer 30. The silicone layer 16 penetrates the porous cover 38 on one side of the protective barrier layer 30 to effect a seal to the protective barrier layer 30. The cover materials can be any fabric, e.g., woven, knit, or nonwoven. The figures illustrate that a wide range of possible sealing backer 20 and protective barrier fabrics may be used with this sealed seam construction.

The Sealing Backer

The sealing backer serves three purposes. First, it forms a bridge across the joint 14 between fabric panels. Second, it forms part of the mold that keeps the liquid silicone in place until it cures. Third, it provides a carrier for the liquid silicone to transport it into the consolidation nip, which lightly compresses the seam.

Once the sealing backer is applied, the sealed seam provides protection against fluids. The backer can have this protective barrier ability by itself, or can supplement it by partial impregnation by the liquid silicone to attain its barrier performance. Preferably, the sealing backer has the barrier performance inherently, i.e., it is or contains a protective barrier layer..

The sealing backer is porous, preferably the pores are microscopic, ie., microporous, to allow penetration of the liquid silicone into the sealing backer, creating a mechanical bond once the silicone sealing layer 16 is cured. Microporous backer materials are preferred, as the liquid silicone can at least partially impregnate the sealing backer 20 and form a mechanical bond between the silicone layer and the sealing backer. By using microporous backer membranes, the pores can be made small enough to provide barrier properties similar to the protective barrier in the protective barrier fabric.. Most

preferably, the backer is expanded PTFE where the liquid silicone easily penetrates and wets the microporous membrane as shown in Figure 2. Figure 2 illustrates liquid silicone 50 penetrating membrane 52, forming a region of silicone that has penetrated in the micropores to form a mechanical bond at 54 between the silicone adhesive layer and the protective barrier fabric. Once cured, this provides a silicone sealing layer 16 (Figure 1) that at least partially penetrates into the pores of the protective barrier layer 30 (Figure 1a), creating a mechanical bond between the two layers. This mechanical bond overcomes the difficulty of bonding silicone to many polymers.

In some uses of this seam construction, it is desirable for the sealing backer to have the appearance of the rest of the garment, or it is desirable to protect the sealing backer from abrasion. In these situations, the sealing backer 20 can have a porous backer cover 32 (as shown in Figure 1b and Figure 1c) where the cover is selected to match the inside of the protective garment or to provide abrasion protection.

Typically the sealing backer 20 is about one inch wide. Some applications with narrow seam allowances can use narrower backer widths. The sealing backer width is selected for the protective barrier fabric and the requirements of the protective garment.

Silicone

A liquid silicone is used to seal and adhere the backer. It can be any of a number of cross-linkable silicones available from several companies worldwide. General Electric RTV 6108 and General Electric LIM® 8040 are typical formulations of addition cured, platinum catalyzed silicones designed for high tear strength and tensile strength, available from General Electric Silicones, Waterford, N.Y. Wacker Elastosil E43 is an example of a condensation cure silicone adhesive, also designed for high strength and available from Wacker Silicones, Adrian, MI. The silicone used in this invention is formulated with fumed silica or other reinforcement to obtain seams durable to flexing and abrasion during use of the garment. The silicone used in the seam construction of this invention generally will be addition cross-linked by an addition mechanism preferably catalyzed by platinum.

Liquid silicones that are cross-linkable are attractive as protective garment sealants because of the large property difference between the

uncross-linked state used to create the seal and the cross-linked state when the garments are in use. For instance, the low viscosity of the uncross-linked liquid silicone allows penetration and sealing of porous layers. Then, the cross-links in the cured elastomer or adhesive, minimize the effect of organic solvents and mechanical handling on the seal.

The process of this invention preferably employs liquid silicones that can be cured in only a few seconds. These are typically addition cured silicone elastomers. A cure temperature is selected to attain a curing time that allows reasonable sealing speeds. It is preferred that the silicone cure in less than 5 seconds at a temperature of less than 150°C. The liquid silicone formulations can be modified by addition of platinum catalyst to speed the cure. Systems that have a cure time of several hours after mixing can be premixed and used in the process as if they were one part systems. Liquid silicone elastomer formulations with a short cure time can be fed in two parts to the process, but the delivery system must provide for mixing the components.

The two-part addition-curable system attains fast cure rates within the heated extended nip 66 (see Figure 3). As described earlier, liquid uncured silicone with fumed silica or other reinforcements are preferred as they result in seals that have the tensile strength and tear strength is needed for durable seams. Preferably, the liquid silicone should cure in less than about 5 seconds at a temperature of 150°C. Those skilled in the art of cross-linked silicone can select suitable formulations from the various suppliers of such silicones. Additionally, it has been found helpful to add additional catalyst, such as platinum, to speed the cure even further, resulting in a cure time of about 2 seconds at a temperature of 120°C.

<u>The Protective Barrier</u>

Protective barrier fabrics typically contain at least two layers, a protective barrier layer 30 and a porous cover layer 36, 38 (see Figures 1a and 1c). The protective barrier layer 30 provides the barrier against the threat the protective garment is to keep away from the wearer. The protective barrier also forms an important part of the sealing backer. This protective barrier layer 30 is preferably microporous, where the surface energy of the material and a small pore size provide the barrier protection.

Microporous polytetrafluoroethylene sheet or film suitable for use in the invention can be made by processes known in the art, for example, by stretching or drawing processes, by papermaking processes, by processes in which filler materials are incorporated with the PTFE resin which are subsequently removed to leave a porous structure, or by powder sintering processes. Preferably the microporous polytetrafluoroethylene film is expanded polytetrafluoroethylene (PTFE) film having a structure of nodes interconnected by fibrils, as described in U.S. Patent Nos. 3,953,566 and 4,187,390, incorporated by reference herein, which describe the preferred material and processes for making them. The nodes and fibrils define an internal structure having a three-dimensional network of interconnected passages and pathways which extend vertically, from surface to surface, and laterally, from edge to edge, throughout the membrane.

The protective barrier layer can be a composite form where a microporous membrane structure is at least partially filled with another barrier polymer. For example, the membrane can be treated on one side of the expanded PTFE membrane with a continuous coating of a nonporous, polyurethane which permits the passage of moisture vapor but shields the expanded PTFE material from oil contamination. One such laminate is disclosed in United States Patent No. 4,194,041 issued March 18, 1980, to Gore et al. and incorporated by reference herein. Other polyurethanes which may be useful for this purpose are described in U. S. Patent No. 4,532,316 issued July 30, 1985, to Henn, U.S. Patent No. 4,942,214 issued July 17, 1990, to Sakhpara, and U.S. Patent No. 5,209,850 issued May 11, 1993, to Abayasekara et al. all incorporated by reference herein. These materials provide a membrane that is waterproof, or resistant to viruses or chemicals, even under conditions of heavy sweat and oil contamination.

The protective barrier fabric 22, 24 in Figure 1 can be a complex construction of several materials or sublayers, each selected for a particular function. For example, a multiple layer flame retardant protective barrier fabric is described in U.S. Patent No. 5,418,054 issued May 23, 1995, to Sun and incorporated by reference herein.

In addition, any component of the sealing backer and/or the protective barrier film may be treated with an oleophobizing agent.

A porous cover layer, such as 36, 38, may be selected to protect the protective barrier layer 30 from abrasion or for aesthetic purposes. The silicone seal in the case of such a two layer protective barrier fabric is directly to the protective barrier layer 30, as shown in Figures 1a and 1b. The surface of the protective barrier layer 30 to which the seal is applied is preferably microporous to allow silicone penetration and mechanical bonding to the protective barrier layer 30. Most preferably, the protective barrier fabric surface is expanded PTFE with one side being treated with the continuous nonporous polyurethane.

Some protective barrier fabrics have an additional inner porous cover layer 38 on the face opposing the outer porous cover layer 36. Like the outer porous cover layer 36, the inner porous cover layer 38 can be a woven, knit, or nonwoven fabric or other polymer form with porosity much greater than the protective barrier layer 30. Sealing such a three layer protective barrier fabric requires the sealant to penetrate through the inner porous cover 38 to the protective barrier layer 30 and to fill the pores in the inner porous cover 38, as shown in Figure 1c. With its low viscosity and low surface energy, liquid silicone can easily penetrate porous covers. For instance, current inner porous covers 38 known in the art typically weigh less than about 2 ounces per square yard and have a very open structure. With liquid silicone, it is possible to seal through inner porous covers 38 with an areal mass up to about 5 ounces per square yard.

The Joint

Figure 1 illustrates a sewn seam with a simple single line of stitching with a seal construction according to this invention. Those skilled in the art of garment construction will know of many types of sewn seams that can be fabricated. An object of this invention is to provide a seam construction that seals a large number of sewn seam types. Since the present invention includes a sealing backer 20 which bridges the joint, the seam seal of this invention can be applied to most sewn seam types, including but not limited to, simple seams, top stitched seams, and felled seams. The joint 14 can be constructed by other methods, as well. Where thermoplastic layers are used in the protective barrier fabrics, such as a nylon fabric protective covering on an expanded PTFE membrane, the joint 14 can be a thermally welded joint. The welded joint can be created by a number of processes, including hot pressing,

ultrasonic welding, and radio frequency welding. The joint 14 will usually be sewn, as sewing is generally used in factories and numerous forms are available to create the joint.

Process

To seal a protective garment seam, a sealing material is applied. While it is desirable to use liquid silicone as sealants for the reasons described earlier, the nature of silicones makes it difficult to use it for garment sealing. It is a part of this invention to provide a process that overcomes these difficulties and provides a method for sealing seams with liquid silicone.

Referring to Figure 3, the process employs an extended nip area 66 for consolidating the sealing backer 20 that is coated onto the seam, and curing the liquid silicone.

The process steps include:

a) coating the liquid silicone onto a sealing backer;

b) applying the sealing backer and the silicone to a fabric seam joint, the silicone being adjacent the joint;

c) passing the coated backer and joint through an extended nip while applying heat; and

d) compressing the joint within the extended nip.

By "extended nip" is meant that contact between two nip rolls, or a roll and a belt, occurs over an extended contact area, rather than at a single point between two rollers as is conventional.

In the process, the sealing backer should be thermally stable and capable of exposure to a temperature of more than 120°C for several seconds, as the sealing backer is exposed to heat during the cure of the silicone polymer.

The process is shown in the schematic in Figure 3. A polymer supply system 60 provides a stream of liquid silicone to applicator 62. Applicator 62 applies the liquid silicone to a sealing backer 20 at a rate suitable for sealing a seam in protective barrier fabric 64. The coated sealing backer 20 is consolidated over the seam in extended nip area 66. Hot roll 72 of the nip provides a source of heat to cure the liquid silicone. The soft opposing surface 68 provides consolidation force and a mold to hold the silicone in place until it is substantially cured. The coated sealing backer 20 and protective fabric are

conveyed through the nip by the rotation of the hot roll 72 and the matching motion of the soft opposing surface 68. A completely sealed seam in protective fabric 70 exits from the extended nip area 66.

Optionally, a postcure step can be performed to complete the cure of the silicone. The liquid silicone is cured at least enough in the extended nip 66 that it is past its gel point and will hold itself together and keep the sealing backer 20 in place. Cure can be completed at room temperature or in a heated postcure step, depending on the characteristics of the silicone formulation selected. Heated postcure can be performed in any number of oven, dryer or other heating systems.

As explained earlier, the liquid silicone supply mix in supply system 60 can take two forms, depending on whether the silicone components are premixed or mixed in the process. In either case, the supply system provides a stream of liquid silicone to the applicator 62, mixed and ready to use and with sufficient back pressure to flow through the applicator 62. Where the silicone components are premixed, the supply system handles only a single component. The supply system can take a number of forms including pumps, pistons or pressure pots. Preferably, the system is a pressure pot with the flow driving force provided by air pressure. The components of such a system are well known and can be selected by one skilled in the art of liquid silicone application.

If a short cure time is desired, a two part delivery system should be used and the two components fed simultaneously to a mixing device. Static and dynamic mixers suitable for this mixing are well known in the art. The output of the mixing device is fed to the applicator 62.

The liquid silicone can be applied to the sealing backer 20 using an applicator. The applicator can take a number of forms, including slit and capillary dies. Capillary dies applying a series of beads to the sealing backer 20 are preferred as they are less sensitive to the coating nip geometry than a slit die. The capillary geometry used depends on the viscosity of the liquid silicone being applied. For systems with a viscosity of about 70,000 CPS up to paste-like systems such as GE Silicones LIM®6745, nine capillaries with a diameter of 0.040 inches and a length of 0.09 inches are preferred to coat one inch wide sealing backer 20. The pressure in the extended nip smoothes the many beads into a substantially continuous layer across the sealing backer 20.

The extended nip area 66 is the region where hot roll 72 and soft opposing surface 68 are in contact with one another. The residence distance is the circumferential length of the extended nip area 66. Preferably the hot roll 72 has a solid non-conformable surface. The preferred residence distance is from about 0.5 inch to about 6 inches. The most preferred residence distance is from about 2 inches to about 3 inches. This is a much longer distance than would be obtained with normal metal or elastomer rolls in a conventional nip configuration. This unusual configuration overcomes a number of the challenges in using silicone elastomers to seal seams. The extended distance of the nip results in adequate residence time in the heated zone to obtain cure of the polymer to past its gel point, overcoming the challenge of the time required for cure and the lack of initial tack to hold components in place. The soft opposing surface 68 and the hot roll 72 together form a mold for the liquid silicone, holding it in place until it is cured.

The hot roll 72 provides the source of heat to cure the liquid silicone elastomer and provides one side of the nip that transports the sealing backer 20 and seam through the nip. Hot roll 72 can be heated by a number of heating methods, including, but not limited to, electric resistance heat, oil heat, and heat transfer vapor heat. Electric heat is preferred, as it can be implemented easily in a process suitable for garment factory use. Care should be taken to assure uniformity of temperature around the hot roll 72.

The soft opposing surface 68 provides radial force, holding the seam and the seal against the hot roll 72 for rapid heat transfer into the sealing backer and silicone adhesive layer. It flexes around the geometry of the seam allowance and sealing backer to form a mold to hold the liquid silicone elastomer in place until it cures. And it helps pull the seam seal and seam through the nip. It can be constructed in several forms, including but not limited to, foam covered rollers, pneumatic or fluid filled rollers, and a belt system. A belt system has been found to be preferable for the simple seam geometry typical of protective liners and medical gowns. A foam roller 80 as shown in Figure 4a is preferred for the more complex seam geometry of rainwear jackets. Figure 4a illustrates the soft opposing surface of extended nip 66 formed by foam covered roll 80. The metal core 82 of the roll is covered by a layer of foam 84. When the nip is closed, foam 84 deforms, allowing a suitable length for extended nip 66. Figure 4b illustrates the soft opposing surface 68

pushing against the hot roll 72 and forming the partial mold to hold the liquid silicone elastomer in place until it cures. Sealing backer 20, seam 10, protective barrier fabrics 22 and 24 and foam covered roll 80 are as previously described. Figure 5 illustrates a variation of the extended nip. In Figure 5, the extended nip 66 is formed by a belt system. Belt 84 is tensioned by a belt tensioner 86, and the tension exerts a force against the hot roll 72. A fiber reinforced silicone belt is preferred as it is soft, thermally stable and conforms to the seam geometry in a manner similar to Figure 4b.

Surprisingly, it has been discovered that a low consolidation force is preferred. It is preferred that the soft opposing surface 68 exert a consolidation pressure of from about 5 pounds per square inch to about 25 pounds per square inch against the hot roll 72. Preferably, the consolidation pressure is about 10 pounds per square inch. This low consolidation force provides contact with the hot roll 72 for heat transfer, helps flex the protective barrier fabric to form a partial mold for the liquid silicone, and minimizes undesired flow of the liquid silicone out the edges of the sealing backer. The extended nip 66 can be constructed with either or both the hot roll 72 and soft opposing surface 68 driven. It is preferred that both be driven, providing the surface speeds are carefully matched.

Without intending to limit the scope of the present invention, the following examples illustrate how the present invention may be made and used:

TEST PROCEDURES

Suter Test

To determine whether a protective barrier fabric or a protective barrier layer or membrane or polymer is waterproof, the Suter test procedure is used. This procedure provides a low pressure challenge to the sample being tested by forcing water against one side of the test sample and observing the other side for indication that water has penetrated through the sample.

The test specimen is clamped and sealed between rubber gaskets in a fixture that holds the specimen so that water can be applied to an area of the specimen 3 inches in diameter (7.62 cm). The water is applied under air pressure of 3 psig to one side of the specimen. In testing a fabric laminate, the water is applied to the face or exterior side. In testing a sealed seam, water is applied to the face side and the sealing backer is observed for leaks.

The other side of the sample is observed visually for any sign of water appearing on the side for 2 minutes. If no water is observed, the sample has passed the test and the sample considered waterproof.

Viral Barrier Test

The viral barrier test, ASTM F1671, is used to measure the resistance of materials used in protective clothing to penetration by blood-borne pathogens, such as Hepatitis and Human Immunodeficiency Viruses. A surrogate microbe suspended in a body fluid simulant is used to challenge the protective clothing under conditions of continuous liquid contact. Pass/fail determinations are based on the detection of viral penetration. The microbe, Phi-X174 Bacteriophage is available from Promega Corporation, Madison, WI. The surface tension of the bacteriophage challenge suspension, with at least 2 x 10^8 plaque forming units/ml, is adjusted to 0.042 +/-0.002 N/m by adding a surfactant, Polysorbate 80, available from Aldrich Chemical Co., Milwaukee, WI. The protective fabric sample is clamped in a pressurization cell with the bacteriophage suspension on the face or exterior side of the sample at a pressure of 2 psig. Penetration of the microbe is detected by plaque assay of the fluid on the opposite side of the sample. Samples with penetration of less than 1 plaque forming unit per milliliter of the assay fluid pass the test. Complete details of this test are available in ASTM F1671.

Example 1

A sealing backer was prepared by dotwise lamination of a knit fabric to a composite barrier membrane and slitting the resulting laminate web into one inch strips.

The composite barrier membrane was a composite of microporous polytetrafluoroethylene (PTFE) membrane coated with a polyurethane, prepared according to U. S. Patent No. 4,194,041 using a water vapor permeable, nonporous polyurethane coating on the ePTFE. A moisture cureable polyurethane adhesive was used. This membrane was laminated, using a plurality of dots of adhesive, to a knit backer cover. The knit was a polyester tricot knit with a weight of 1.8 ounces per square yard. The knit was adhered to the polyurethane coated side of the film, leaving a surface of

microporous expanded PTFE as the surface to which the liquid silicone sealant is applied.

Several samples illustrating the seam construction with a variety of protective barrier fabrics and sealing backers were fabricated as shown below. The samples were fabricated by coating strips of the sealing backer with liquid silicone using a draw knife. The coated sealing backer was placed over a seam and the silicone was cured in a heat press. More specifically, a two part liquid silicone were metered and mixed in a ratio specified by the manufacturer using volumetric metering cartridges and a hand pumped MixPak® volumetric metering system supplied by ConProTec, Inc., Salem, NH. Mixing was accomplished using a 12 element static mixer attached to the cartridge. The silicone formulations used contained fumed silica. At least three strips of sealing backer were taped to a surface and a drawknife was positioned over the strips with the selected draw knife gap positioned on the outer sealing backer strips. The drawknife was positioned over the set of strips such that the drawknife edges were on the outer strips, establishing a gap between the sealing backer strips and the draw knife that did not depend on the thickness of the sealing backer. Liquid silicone was applied near the drawknife from the meter/mixing system and drawn into a film over the sealing backer strips by manually sliding the draw knife along the strips of sealing backer. The coated sealing backer strip was positioned over the seam to be sealed and pressed into place by hand. The seam and coated sealing backer were then sealed in a heat press that has a heated platen on the top and a foam pad on the bottom (a GORE-SEAM® Crossover Press of W. L. Gore & Associates, Elkton, MD). The closure was adjusted to gently compress the foam with the seam in the press. The press platen temperature was 350°F and samples were heated for 2 minutes to cure the silicone. The samples were held at 23°C for at least 24 hours.

The samples were tested for waterproofness by the Suter Test. All samples passed the test at 3 psi, except Sample 6, which only held 2 psi without leaking.

The samples in this example illustrate the wide variety of protective barrier fabrics and sealing backers that this seam construction enables, demonstrating that the construction can be applied to a broad range of fabrics and seams. Samples 1-3 form a seam construction according to Figure 1a

where the liquid silicone is applied directly to the protective barrier layer of the fabric and the sealing backer which has no optional backer cover. Samples 4-8 form a seam construction according to Figure 1b where the sealing backer has a backer cover. Samples 9 and 10 form a seam construction according to Figure 1c where the silicone elastomer penetrates and substantially fills the pores in a porous cover layer in the protective barrier fabric before it reaches and forms a seal with the protective barrier layer. All samples except Sample 3 contained a microporous membrane in the sealing backer.

It should be clear from the examples that the construction of this invention can be applied to a number of protective barrier fabrics including microporous, protective barriers. Data relating to these samples is provided in Table 1.

Table 1. Samples Fabricated According to Example 1.

Sample	*Sealant Silicone 1*	*Sealant Source*	*Sealing Backer* g/m^2	*Protective Barrier Fabric 2, 3, 4*	*Protective Barrier Fabric Source*	*Draw Knife Gap*
1	RTV 1529 PEX	Rhone Poulenc Silicone	75	2 layer laminate with ePTFE sealing surface	WL Gore & Assoc. P/N 213295	0.02cm
2	RTV 863	Rhone Poulenc Silicone	75	2 layer laminate with ePTFE sealing surface	WL Gore & Assoc. P/N 213295	0.02cm
3	RTV 1529 PEX	Rhone Poulenc Silicone	0.005cm thick nylon film, DuPont Dartek®	2 layer laminate with ePTFE sealing surface	WL Gore & Assoc. P/N 213295	0.02cm
4	RTV 1529 PEX	Rhone Poulenc Silicone	According to Example 1	2 layer laminate with composite sealing surface	WL Gore & Assoc. P/N 213221	0.02cm
5	RTV 1529 PEX	Rhone Poulenc Silicone	According to Example 1	2 layer laminate with ePTFE sealing surface	WL Gore & Assoc. P/N 213295	0.02cm
6	RTV 1529 PEX	Rhone Poulenc Silicone	According to Example 1	2 layer laminate with microporous polyurethane surface	2 layer woven fabric with Ultrex® membrane from Burlington	0.02cm
7	RTV 1529 PEX	Rhone Poulenc Silicone	According to Example 1	2 layer laminate with Monolithic polyetherpolyester sealing surface	2 layer woven fabric with Sympatex® membrane from Akzo Nobel	0.02cm
8	RTV 1529 PEX	Rhone Poulenc Silicone	2 layer Ultrex® woven fabric with membrane slit to 1 inch wide	2 layer laminate with microporous polyurethane surface	2 layer woven fabric with Ultrex® membrane from Burlington	0.02cm
9	RTV 1529 PEX	Rhone Poulenc Silicone	According to Example 1	3 layer laminate with composite membrane sealing surface	WL Gore & Assoc. P/N 313316	0.02cm
10	RTV 1529 PEX	Rhone Poulenc Silicone	According to Example 1	3 layer laminate with ePTFE sealing surface	WL Gore & Assoc. P/N 311364 (OR)	0.038cm

1. All silicone sealants were the two part, addition curable type that contained fumed silica.
2. The 2 layer laminate of Samples 1, 2, 3 and 5 contain an ePTFE membrane laminated to a woven nylon fabric.
3. The 2 layer laminate of Sample 4 includes an ePTFE membrane, partially filled with a breathable polyurethane, and laminated to a woven polyester fabric. The seal is to the polyurethane-filled surface of the composite membrane.
4. The 3 layer laminate of Sample 9 includes an ePTFE membrane, partially filled with a breathable polyurethane, laminated on one side to a woven polyester fabric and on the other to a polyester knit fabric. The polyurethane-filled surface of the composite membrane is toward the knit and the seal is applied on this side.
5. The 3 layer laminate of Sample 10 includes an ePTFE membrane, partially filled with a breathable polyurethane, laminated on one side to a woven polyester fabric and on the other to a polyester knit fabric. The polyurethane-filled surface of the composite membrane is toward the woven fabric and the seal is applied on the knit side to an ePTFE surface.

Example 2

A machine with the nip construction shown in Figure 4 was used. The hot roll had a diameter of 4 inches. The foam roll had an outer diameter of 4 inches with 0.75 inches of foam covering an aluminum inner core. The foam roller was formed by molding GE RTF 7000 foamed silicone formulation, available from General Electric Silicones, Waterbury, N. Y., onto the core in a mold with a 4 inch diameter cavity. The foamed silicone was prepared according to the manufacturers directions with 125.1 g of RTF 7000 and 9.7 g of RTF 7110. Sealing backer, formed according to Example 1, was drawn by the nip past an applicator with nine 0.040 inch diameter capillaries. Mixed liquid uncured silicone was supplied to the applicator from a small pressure pot connected to the applicator by a 3/8 inch diameter feed tube. The silicone was General Electric LIM® 6745 with 10 parts per million additional platinum catalyst added. The silicone also contained fumed silica. Mixing was by hand. The silicone was degassed for 30 minutes before loading into a pressure cartridge. A pressure of 15 psi was applied to the pressure cartridge. The coated sealing backer was conveyed through the extended nip at 2 ft/min and applied to a sewn seam between two barrier fabric panels with ePTFE surfaces (W. L. Gore Part Number 214285). The panels were composed of a composite membrane, consisting of a flame retardant polyurethane layer sandwiched between two layers of ePTFE, adhered to a nonwoven Nomex® E89 fabric from Du Pont. A pressure of 30 psi was applied to the nip, resulting in an extended nip distance of 1.5 inch. A hot roll temperature of 178 C was used. The resulting sealed seam passed a Suter test with 2 min at 3 psi after a 24 hour room temperature postcure period.

Example 3

A sealing machine with an extended nip formed by a tensioned belt was constructed. The belt had a width of 2 inches and contacted a 4 inch hot roll set for 200°C. The belt was fiber reinforced silicone. A sealed seam was formed with the same sealing backer, polymer, and applicator system of Example 2 by applying the polymer and consolidating in a 1.5 inch long nip with a hot roll temperature of 190°C and a speed of 15 feet per minute on a seam in protective barrier fabric with an expanded PTFE surface (W. L. Gore Part Number 214285). The barrier membrane in this fabric contains a layer of

ePTFE adhered to another layer of ePTFE by a fire retardant polyurethane adhesive containing phosphorous.The belt was tensioned to apply a pressure of 10 psi against the hot roll. The resulting sealed seam passed the Suter test at 3 psi for 2 minutes; and passed the viral barrier test according to ASTM F1671.

The invention claimed is:

1. A protective barrier fabric having a seam, said seam being covered by a sealing backer; said backer adhered to the fabric by cross-linked silicone that contains a reinforcing material, said silicone forming a waterproof seal between the fabric and the sealing backer.

2. The fabric of claim 1 where the sealing backer has a protective barrier layer.

3. The protective barrier fabric of claim 1 in which the backer comprises a protective barrier layer of membrane and a cover layer.

4. The protective barrier fabric of claim 1 in which the silicone contains platinum.

5. The protective barrier fabric of claim 3 wherein the sealing backer membrane is microporous.

6. The protective barrier fabric of claim 5 wherein the sealing backer is microporous polytetrafluoroethylene.

7. The protective barrier fabric of claim 6 wherein the sealing backer is expanded polytetrafluoroethylene.

8. The protective barrier fabric of claim 1 wherein the protective barrier fabric includes an expanded polytetrafluoroethylene layer.

9. The protective barrier fabric of claim 8 wherein the expanded polytetrafluoroethylene layer is coated with a water vapor permeable, nonporous polyurethane.

10. The protective barrier fabric of claim 1 wherein the protective barrier fabric comprises:

a first layer of expanded polytetrafluoroethylene;

a second layer of expanded polytetrafluoroethylene; and

a layer of phosphorous containing poly (urea-urethane) adhesive between said first and second layer of expanded polytetrafluoroethylene.

11. The protective barrier fabric of claim 1 wherein the seal withstands degradation upon exposure to heat at a temperature of 500°F for five minutes.

12. The protective barrier fabric of claim 1 wherein the fabric passes the viral barrier test.

13. The protective barrier fabric of claim 1 wherein the fabric passes the Suter test.

14. A method for sealing joints in protective barrier fabrics comprising the steps of:

a) coating a liquid silicone onto a sealing backer;

b) applying the sealing backer with the silicone to a joint, the silicone adhesive layer adjacent to the joint; and

c) compressing sealing backer, silicone and joint within a heated extended nip.

15. The method of claim 14 wherein the extended nip has a residence distance of from about 0.5 inch to about 6 inches.

16. The method of claim 14 wherein the pressure between the extended nip and the hot roll is from about 5 psi to about 25 psi.

17. The method of claim 14 wherein the extended nip is formed by a foam roller compressed against a solid roller.

18. The method of claim 14 wherein the extended nip is formed by an elastomer belt compressed against a solid roller.

19. The protective barrier fabric of claim 1 included in a garment.

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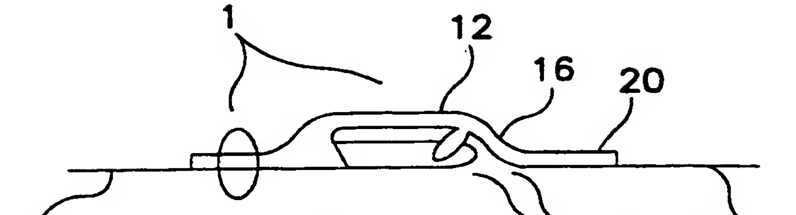


FIG. 1

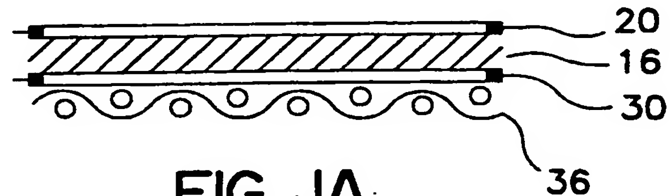


FIG. 1A

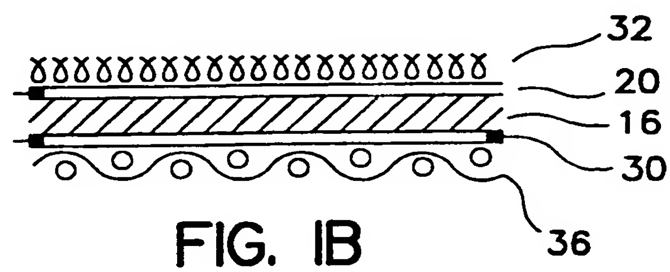


FIG. 1B

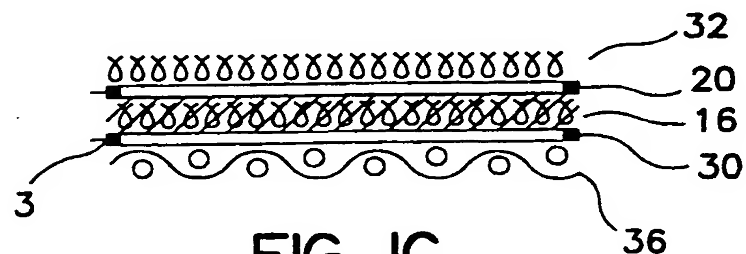


FIG. 1C

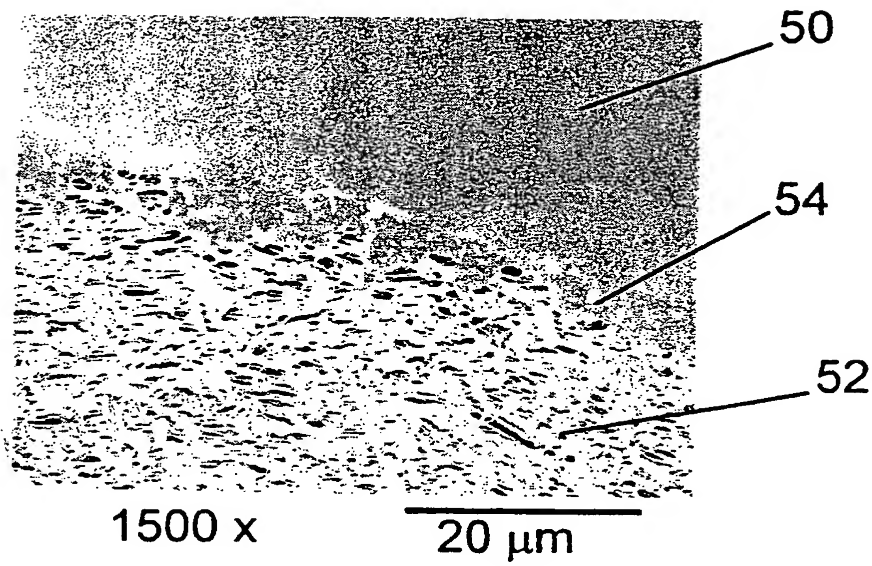


FIG. 2

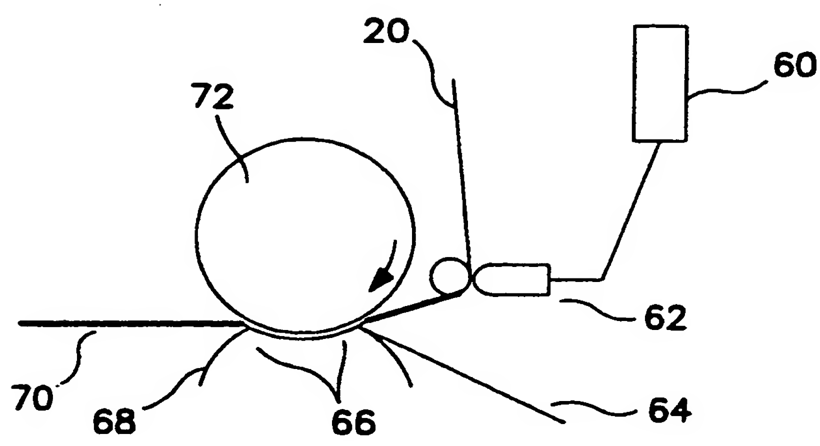


FIG. 3

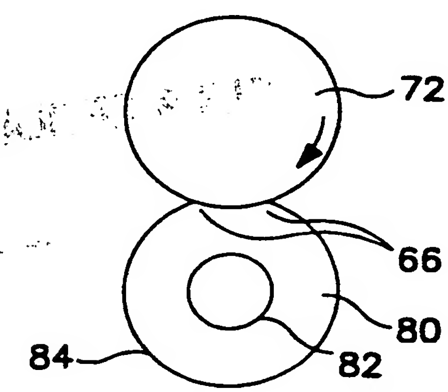
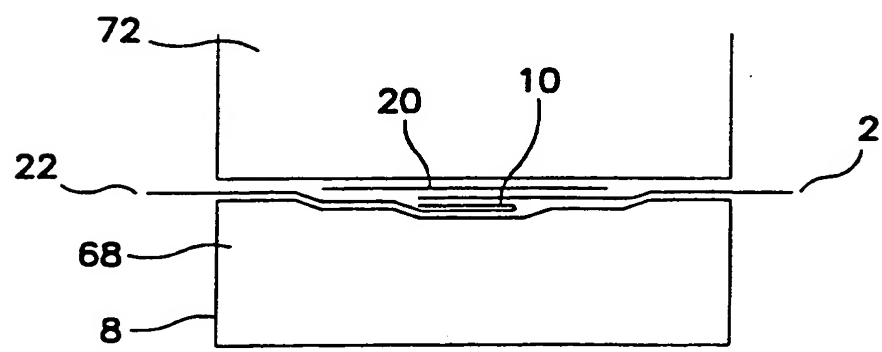


FIG. 4A



SECTION A–A

FIG. 4B

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/27286

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A41D27/24 B29C65/50

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A41D B29C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 February 2001	02/03/2001

Name and mailing address of the ISA	Authorized officer
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